IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"NON-LINEAR ANALYSIS OF REINFORCED CONCRETE BEAM STRENGTHENED WITH FIBRE REINFORCED POLYMER (FRP) SHEET"

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Abstract: The maintenance, rehabilitation and upgrading of structural members, is one of the most important (crucial) problems in civil engineering applications. A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For domestic building, this design life could be twenty-five years, whereas for a public building it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration can be mainly due to environmental effects. In these effects, corrosion of steel, gradual loss of strength with aging, repeated high intensity loading, variation in temperature, freeze and thaw cycles and contact with chemical & saline water. Since replacement of such deficient elements of structures will be costly, strengthening has become the acceptable way of improving their load carrying capacity and extending their service life. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure.

Keyword - Maintenance, Rehabilitation, Public Building.

I. INTRODUCTION

The construction material mainly concrete is being used extensively for various types of construction projects. However, the deterioration of Reinforced Concrete structures is recognized as a major problem worldwide. Apart from requiring regular maintenance, many structures require extensive Repair/Rehabilitation/Retrofitting. Over a period, as these structures become older, we find in them certain degradation or deterioration with resultant distress manifested in the form of cracking,splitting, delaminating, corrosion etc. Typically, conventional methods of retrofitting of concrete structure are Addition of Shear Walls and Infill's, addition of steel braces. Following are the limitations of conventional retrofitting methods, which create a requirement of an innovative approach in retrofitting of structures. While increasing the stiffness of the structure, the natural period of vibration decreases inevitably. This increases the earthquake demand in cases such as, Long period structures lying beyond acceleration-controlled range Structures built on rocky or medium soil, where limit for acceleration-controlled range is small. However, for construction of shear walls large number of business hours are spent in construction.Also, due to increased forces frame column and foundation need to be strengthened again. The new construction occurring may not account for the openings' spaces i.e. for doors and windows.

Materials and Methods:-

1.Materials:-

Cement: Portland pozzolena cement (PPC) (Brand: Ultratech) of 43 grade is used for the experiment.

Fine Aggregate: The fine aggregate passing through 4.75 mm sieve and having the specific gravity of 2.8 are used.

Coarse aggregate: The coarse aggregate passing through 20 mm sieve and the specific gravity of 2.9 are used.

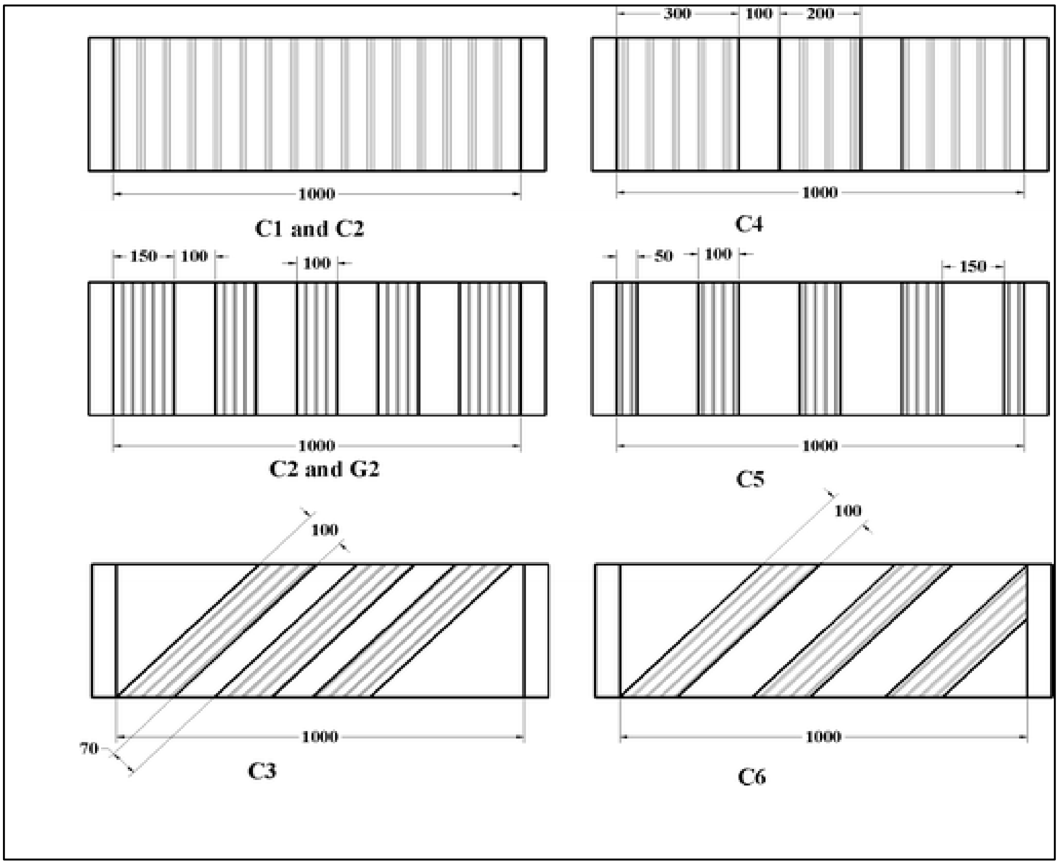
Water: Ordinary tap water is used for mixing in all mix.

Reinforcing steel: All the beams are reinforced with two 8 mm bars at the bottom and top reinforcement throughout the length and 6 mm bar stirrups is used. Tor steel of Fe500 Grade is used.

2 Experimental Investigation:-

The purpose of this research is to investigate the flexural and shear strengthening of RC beams with various types of FRP wrapping. In this research the nine beams are casted and tested up to failure. These beams are strengthening with the help of GFRP and CFRP sheets with epoxy resin. In this investigation the beams are divided into three groups-GFRP beams, CFRP beams and mix GFRP & CFRP beams which are strengthened by using FRP strips in pattern. The purpose of this research is to investigate the shear behavior of reinforced concrete deep beams strengthened with different patterns of GFRP and CFRP on the strength and ductility of beams are investigated. Beams are cast and test up to failure. In this study total 9 beams are cast, out of these two is controlled beam and other will be strengthened glass fiber reinforced polymer (GFRP) sheets and carbon fiber reinforced polymer (CFRP) sheets in flexure as well in shear. Two point load test are taken as per IS: 2185 (PART 4)-2008.

Preparation of test Specimen:-



Test Setup :-

All the specimens will be test on the UTM of the "Structural Engineering" Laboratory of the testing procedure for the entire specimen is same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed

Experimental Setup for Testing of Beam

II. OBJECTIVES

- To investigate non-linear analysis of reinforced concrete beam without wrapping of FRP sheet.
- To investigate non-linear analysis of reinforced concrete beam with wrapping of FRP sheet
- To compare the results obtained.
- To validate above results. .

III. METHODOLOGY

- **Step 1 :-**Determining properties of ingredients of concrete
- **Step 2 :-** casting RC beams and determining its mechanical properties in fresh state and in hardened state without FRP wrapping.
- **Step 3 :-** casting RC beams and determining its mechanical properties in fresh state and in hardened state with FRP wrapping .comparison of result.
- **Step 4 :-**comparison of result.
- **Step 5 :-**validation of results .

IV.RESULTS AND ANALYSIS

Testing Of Normal Beams:- All the nine beams are tested one by one. All of them are tested in above arrangement. The gradual increase in load and the deformation are taken throughout the test. The load at which the first crack is developed is known as cracking load and the load is applied till the ultimate failure of the beam. The deflection of the span is taken for all the beams are recorded with respect to increase in load. The normal beams showed the wide flexural cracks. Generally beams showed three major cracks which was occurred at mid span of the beam and below the point of applied load. The small cracks were occurred near the wide cracks and support of the beam. All of the beams some beams were showed the vertical cracks below the point of loading near support which is known as shear cracks. The cracks were occurred at mid span of the beam are known as flexural cracks. The above figures shows the different types of cracks occurred during testing of the beams under uniform increase in applied load. The ultimate load of the normal beams G1 , G2 , G3 , C1 , C2 , C3 , M1 , M2 and M3 are 92.72 KN , 97.36 KN , 102.36 KN , 91.68 KN , 110.68 KN , 95.88 KN , 100.02 KN , 99.56 KN and 101.44 KN respectively.

2.Testing Of Strengthened Beam:-

All the normal beams after testing are rehabilitated and strengthened with GFRP and CFRP sheets. In this the beams were divided into three groups G , C and M. Each group consists of three beams. The G group beams were strengthened with GFRP strips , C group beams were strengthened with CFRP strips and the M group beams were strengthened with GFRP and CFRP strips. All the beams were tested up to ultimate load and deflection of the beams with respect to increase in applied load were recorded. After testing the strengthened beams with GFRP and CFRP showed the failure of the beams due to the debonding of the FRP sheets and concrete surface of the beam. This was the main reason caused failure of beams. In some cases the strip at tension side was broken and failure of beam occurred. The cracks occurred on strengthened beams were less wide as compared to the cracks occurred on the normal beams. The ultimate load on the beams G1 , G2 , G3 , C1 , C2 , C3 , M1 , M2 and M3 were 139.68 KN , 144.90 KN , 146.58 KN , 125.66 KN , 159.66 KN , 202.44 KN , 151.06 KN , 209.94 KN and 142.70 KN respectively.

3.Test Result And Discussion

All the nine beams are tested one by one. All of them are tested in above arrangement. The gradual increase in load and the deformation are taken throughout the test. The load at which the first crack is developed is known as cracking load and the load is applied till the ultimate failure of the beam. The deflection of the span is taken for all the beams are recorded with respect to increase in load.

EXPERIMENTAL RESULT OF THE TESTED BEAM FOR SET OF G,C,M

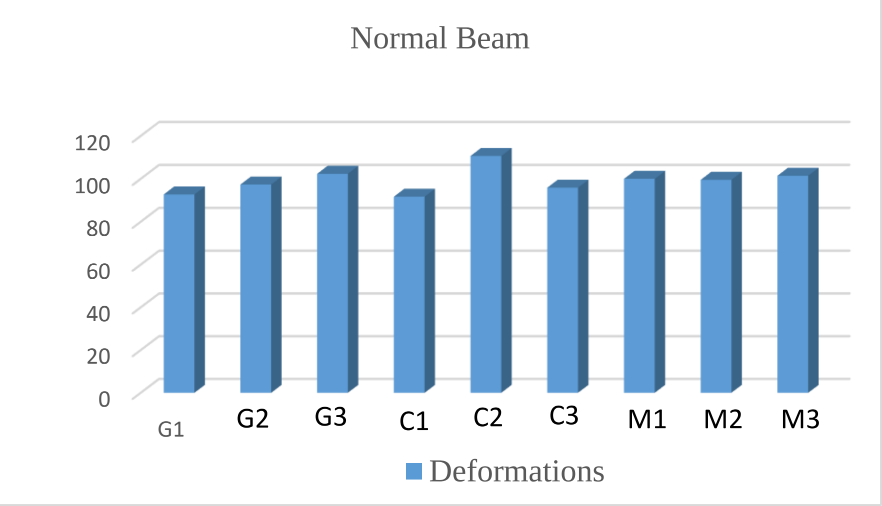
Sr. No.	Ultimate load of normal beams in KN	Ultimate load of Rehabilitated and Strengthened beams with GFRP and CFRP and Epoxy Resin in KN	% of loading increases
G 1	92.72	139.68	50.64 %
G 2	97.36	144.90	48.83%
G 3	102.36	146.58	43.20%
C 1	91.68	125.66	37.06%
C 2	110.68	159.66	44.25%
C 3	95.88	202.44	111.14%
M 1	100.02	151.06	51.03%
M 2	99.56	209.94	110.87%
M 3	101.44	142.70	40.67%

Comparison of loading between normal beams and strengthened beams with GFRP &CFRPsheets.

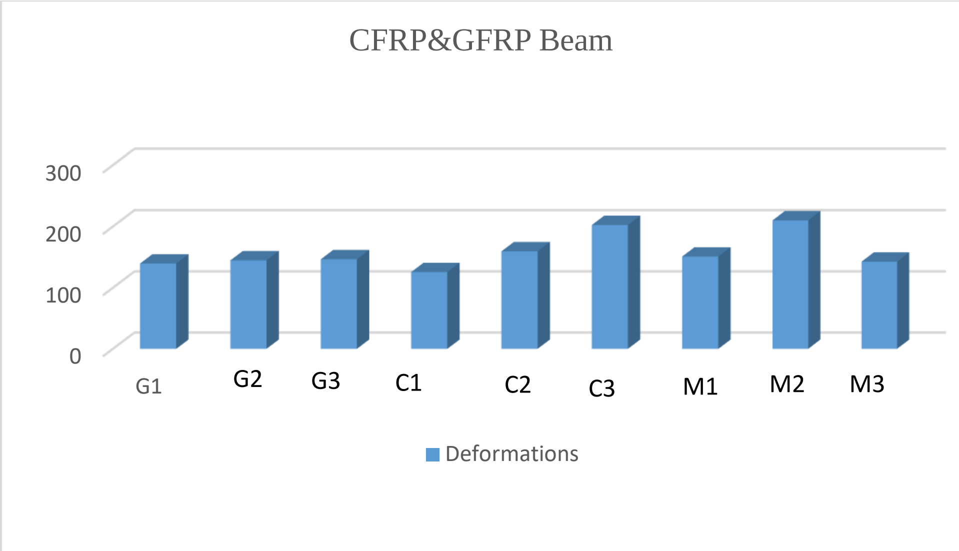
From the above table, it was conclude that the average ultimate load carrying capacity of strengthened beams G 1, G 2, G3 with GFRP strips was increased by 47.55% as compared to the load carrying capacity of normal beams. The average ultimate load carrying capacity of strengthened beams C 1, C 2, C 3 with CFRP strips was increased by 64.15% as compared to the load carrying capacity of normal beams. The average ultimate load carrying capacity of strengthened beams M 1, M 2, M 3 with GFRP and CFRP strips was increased by 67.52% as compared to the load carrying capacity of normal beams.

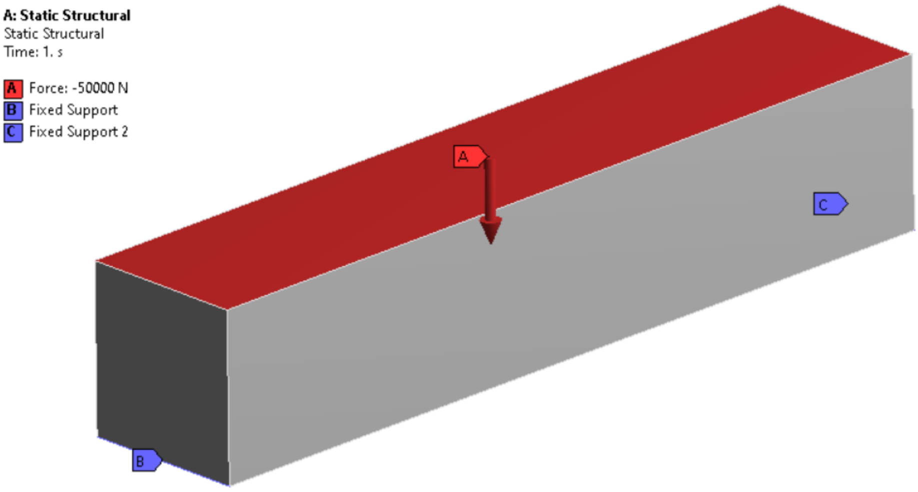
4.LOAD DEFLECTION :-

Normal Beam Deformations for 50 kN Load		
Sr no	Ultimate load	Deformations
1	92.72	4.895
2	97.36	5.072
3	102.36	4.611
4	91.68	4.784
5	110.68	5.496
6	95.88	5.032
7	100.02	5.0501
8	99.56	5.038
9	101.44	5.099

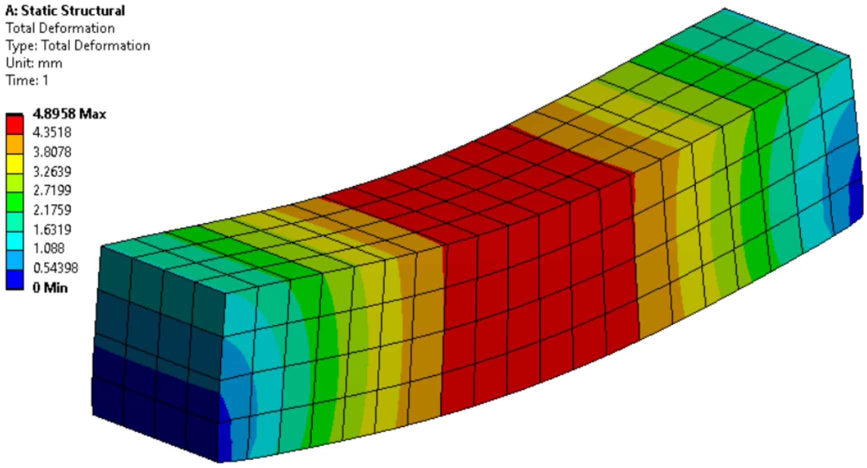


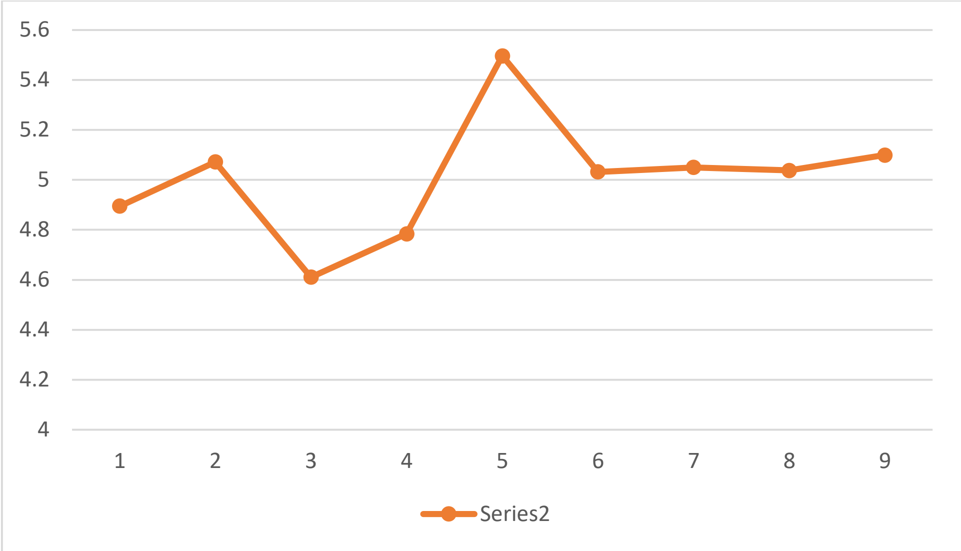
CFRP&GFRP Beam Deformations for 50 kN Load		
sr no	Ultimate load	Deformations
1	139.68	5.808
2	144.9	5.904
3	146.58	5.948
4	125.66	5.506
5	159.66	6.208
6	202.44	6.999
7	151.06	6.038
8	209.94	7.118
9	142.7	5.868



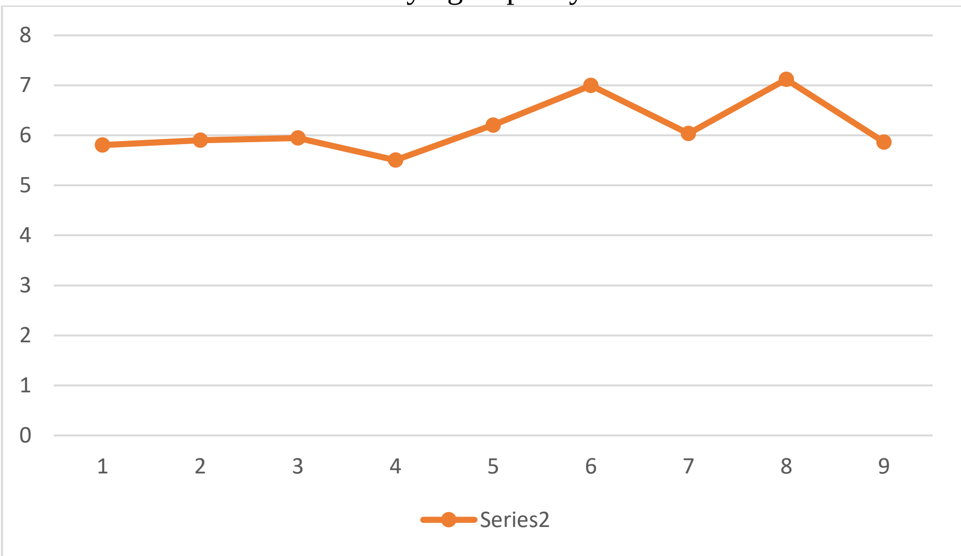


Model of Beam





Ultimate Load Carrying Capacity of Normal Beam



Ultimate Load Carrying Capacity CFRP & GFRP Sheet Wrapped Beam

CONCLUSION

- The present experimental investigation is carried out on flexural behavior of reinforced concrete rectangular beams. In this experiment nine reinforced concrete beams are casted. The beams were divided into two series G and C and M series beams consist of normal beams which were tested up to failure..The series beams are divided into three groups G, C and M. The G, C & M group beams were rehabilitated and strengthened by GFRP, CFRP and mix GFRP & CFRP sheets respectively. From the test results, calculated strength and cost, the following conclusions are drawn:
- 1)The initial cracks in the rehabilitated and strengthened beams are formed at higher load compared to normal beams.
- 2)The ultimate load carrying capacity of rehabilitated beams is higher when compared to the normal beams.
- 3)From G group, the beams which were strengthened by GFRP sheets have average increased ultimate load carrying capacity was 47.55% as compared to the normal beams.
- 4)From C group, the beams which were strengthened by CFRP sheets have average increased ultimate load carrying capacity was 64.15% as compared to the normal beams.

- 5)From M group, the beams which were strengthened by CFRP sheets at tension face and mid span of the beam and remaining portion of the beam was strengthened by GFRP sheets. Their average ultimate load carrying capacity was 67.52% as compared to the normal beams.

- 6)Among these three types of strengthening beams mix beams gives higher strength as compared to other type of beams and which is also economical. Followed by it the C group beam shows more strength and after this G group beams show more strength as compared to the cost.

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Figure 1 a structure of high-rise building and different type of bracings

Braced Framed

A braced frame is a cantilevered vertical truss that resists lateral loads, especially diagonal elements. Beams and columns act as "chords" and the webs are made up of other vertical truss components, "webs" and "webs". Beams and columns cannot bend due to bracing elements. It is used for steel structures. For multi-story structures between lower and middle floors, this approach is suitable. Effectively and cost-effectively increases the lateral stiffness and strength of rigid frame systems. This system allows the use of thin members in buildings. Braced frames have the amazing advantage of being repeatable up to the height of the building, but they are more economical to design and build. The arrangement can also be disturbed. To do this, it must be internally integrated with walls and barriers.

Figure 2 braced frame structure

Rigid Frame

In a rigid frame structure, the columns and beams are built as a unit to resist the moment due to the load. The bending stiffness of the in-plane columns, beams, and connections determines the lateral stiffness of the rigid frame. Can be used in reinforced concrete buildings. It can also be used in steel buildings, but it is expensive to connect. The possibility of designing and installing windows with an open rectangular arrangement is one of the advantages of rigid frames. Rigid frame system components can withstand axial loads, shear forces, and bending moments. A 20-25-story building can be built using the Rahman structure. Buildings are simple, workers learn skills quickly, construction is quick, and sturdy frames are affordable. The maximum beam span is 12.2 meters and the longer beams are overhanging on the sides. The fact that the movement of the inflexible frame resists its own weight is a drawback. Burj Al Khalifa, the tallest building in the world, was built with the Rahman method.

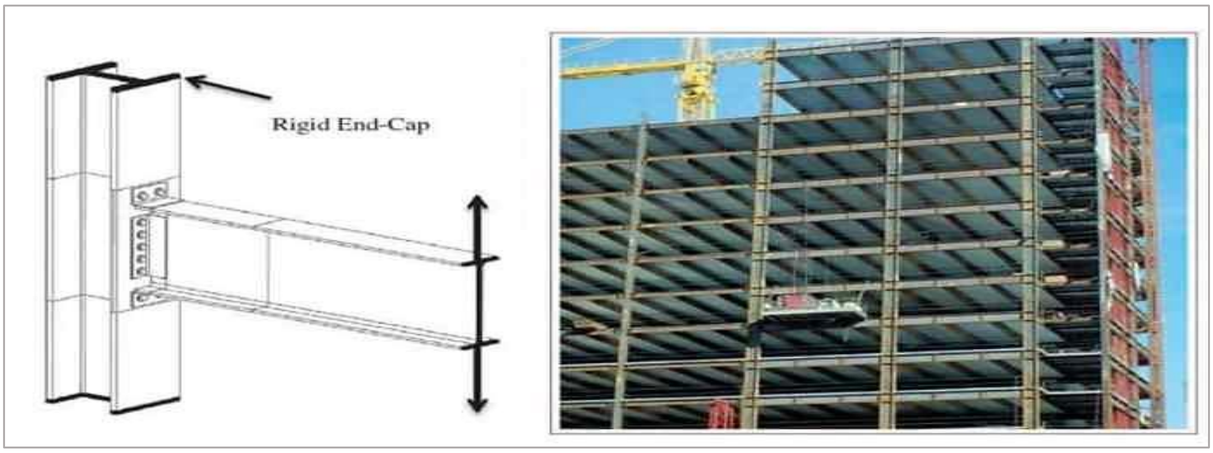


Figure 3 rigid frame

Wall Frame

The walls and frames are in horizontal contact to create a stronger and more rigid structure. In most cases, stairways, elevator shafts, and/or exterior walls of buildings are solid (ie, not pierced by openings). For example, walls may improve frame performance by preventing soft stories from collapsing. Compared to shear or rigid frames alone, wall frame systems are more suitable for 40-60 story structures. The benefits of horizontal interaction are the same for braced and rigid steel frames.

Figure 4 wall frame structure

II. OBJECTIVES

- To analyze a 30-storey RCC structure with a shear wall subjected to earthquake loading in ETABS software.
- To compare the storey drifts received on the shear walls and retrieve the drift ratios and storey displacements from it.
- To suggest the suitable lateral load resulting system from the outcome of the above study.
- To compare the results with the manual method results.

III. METHODOLOGY

Geometrical Analysis

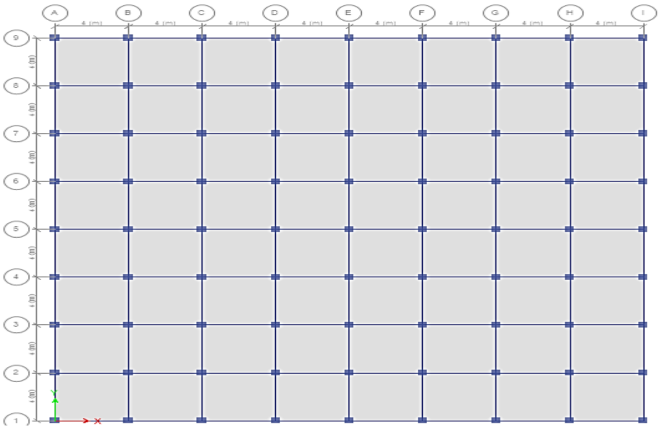
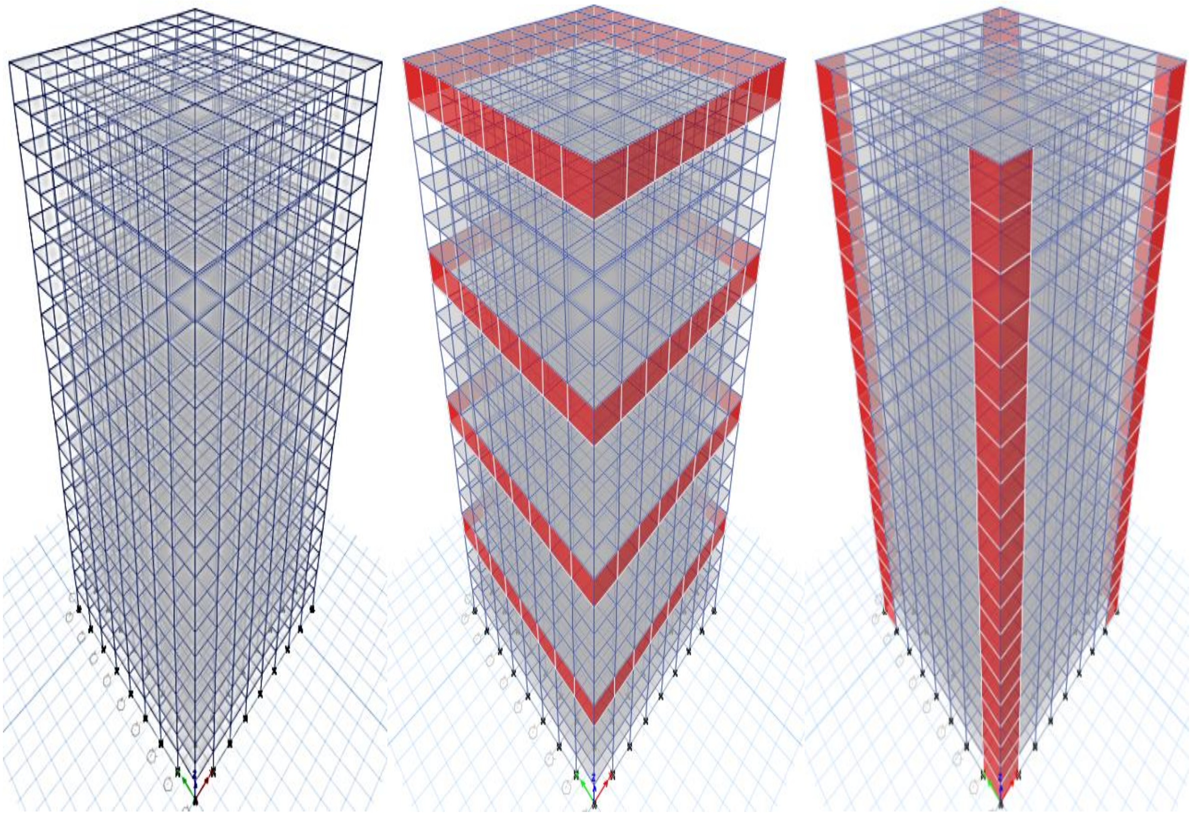


Figure 5 plan view of bare frame



a) RCC Bare Frame b) Bare frame with Belt wall c)Bare Frame with Shear Wall

Figure 6 3d view of structure in various cases

IV. RESULTS AND ANALYSIS

Joint Displacement

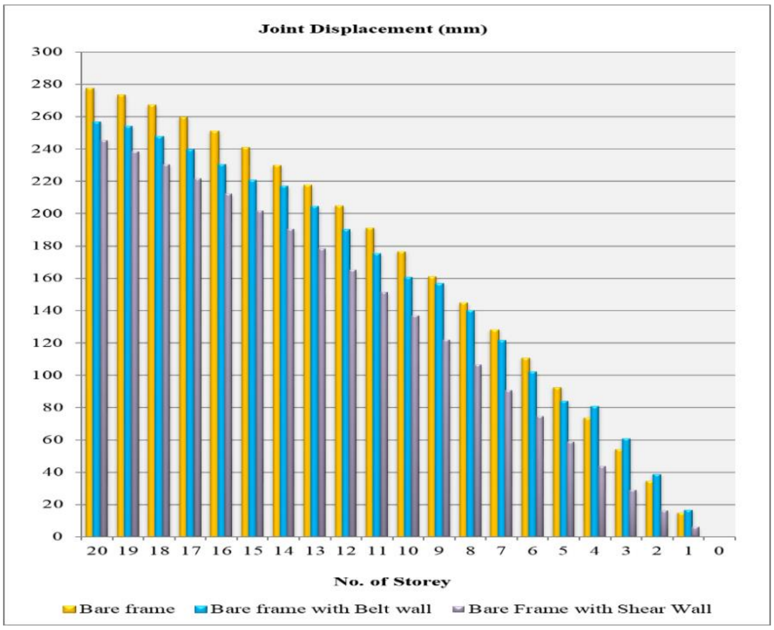


Figure 7 joint displacement in structure with application of belt wall and shear wall due to load combination 1.0 (DL+EQL)

Storey Drift

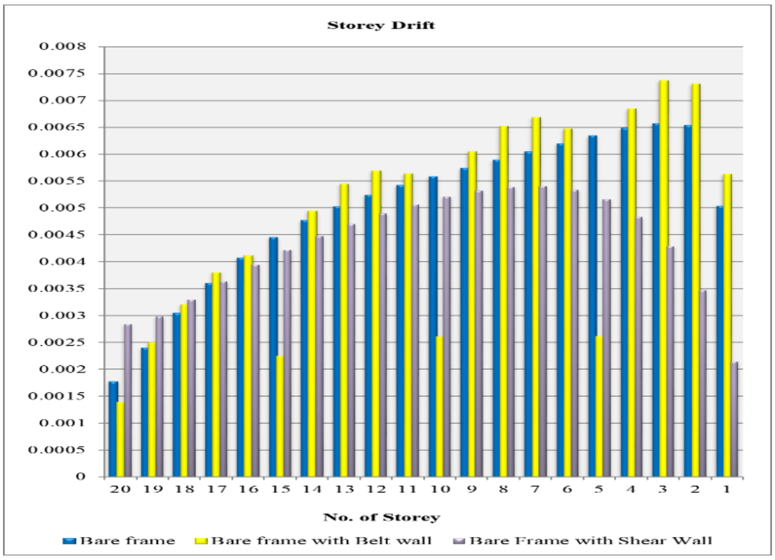


Figure 8 storey drift in structure with application of belt wall and shear wall due to load combination 1.0 (DL+EQL)

Drift Ratio

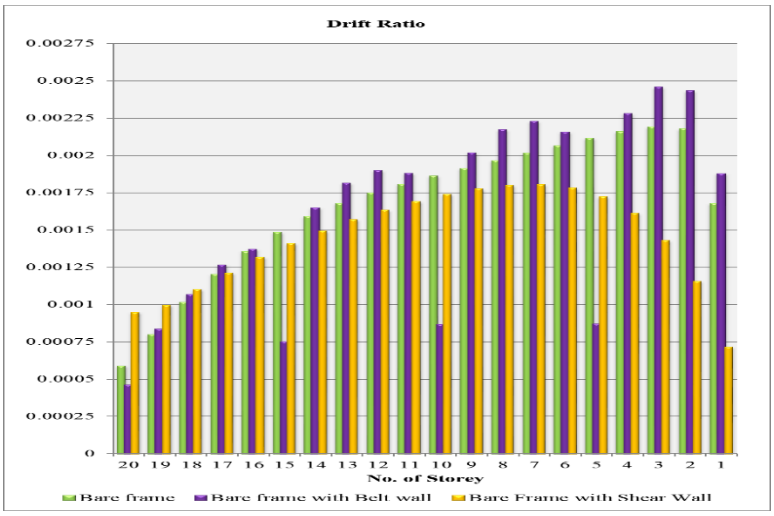


Figure 9 drift ratio in structure with application of belt wall and shear wall due to load combination 1.0 (DL+EQL)

Bending Moment

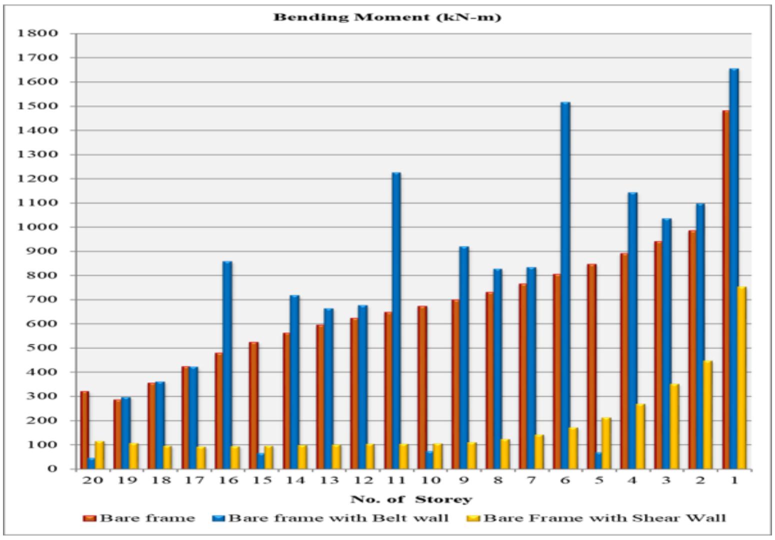


Figure 10 bending moment in structure with application of belt wall and shear wall due to load combination 1.5 (DL+EQL)

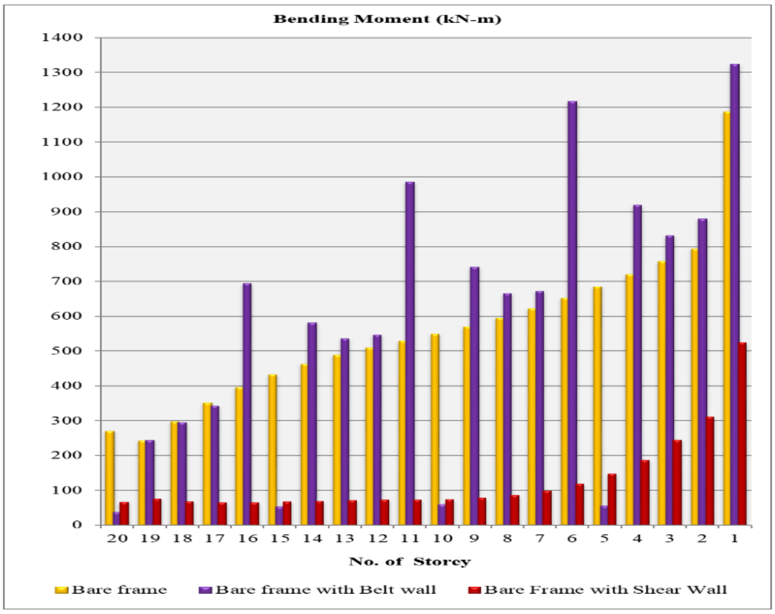


Figure 11 bending moment in structure with application of belt wall and shear wall due to load combination 1.2 (DL+LL+EQL)

Shear Force

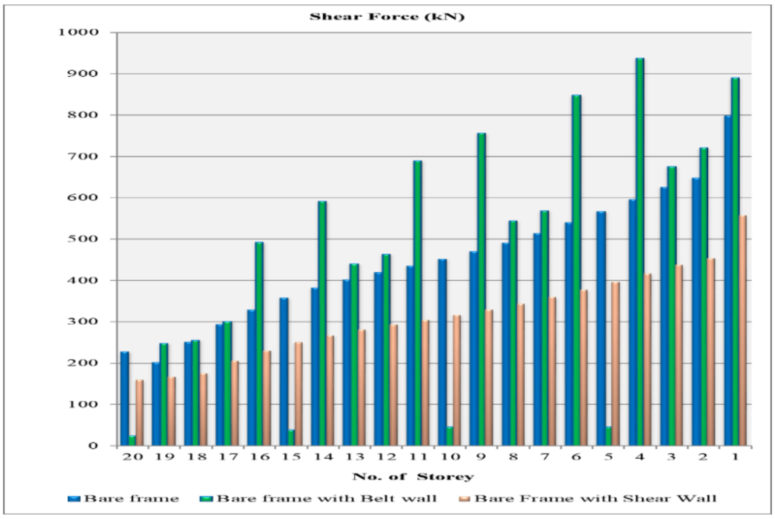


Figure 12 shear force in structure with application of belt wall and shear wall due to load combination 1.5 (DL+EQL)

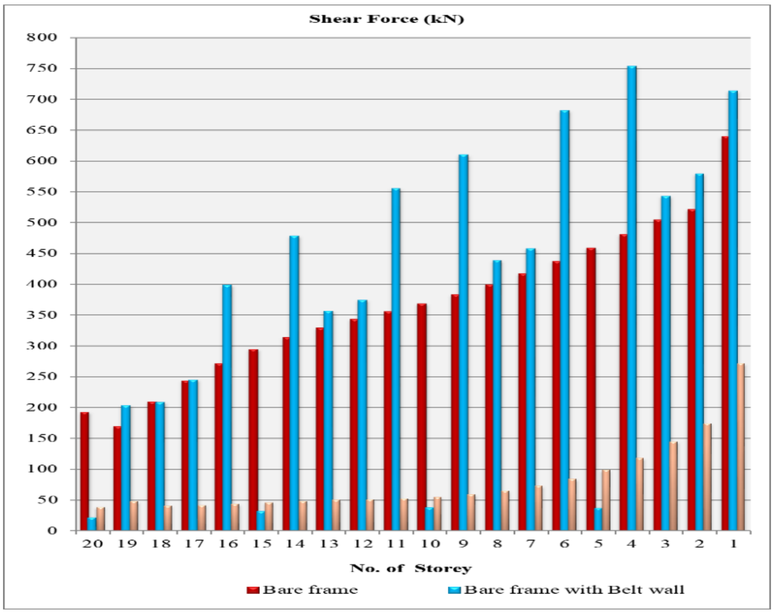


Figure 13 shear force in structure with application of belt wall and shear wall due to load combination 1.2 (DL+LL+EQL)

Base Shear

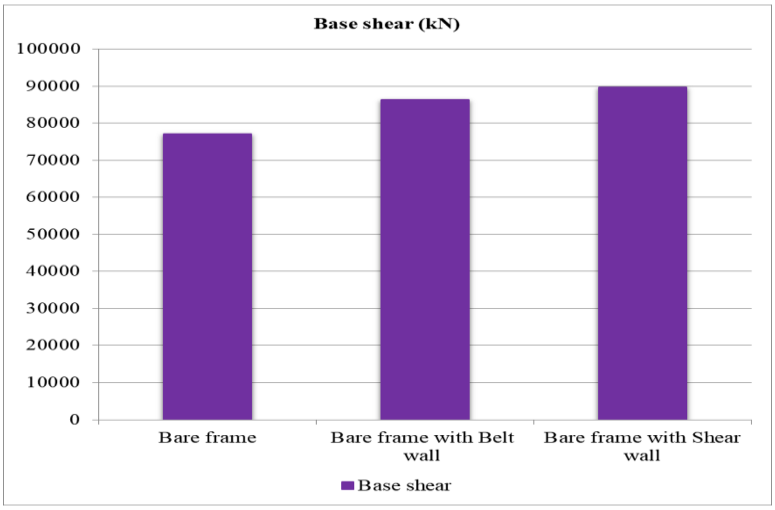


Figure 14 base shear in structure with application of belt wall and shear wall due to load combination 1.2 (DL+LL+EQL)

V. CONCLUSION

- In 20 storey building maximum Joint Displacement in Bare frame occurs due to load combination 1.0 (DL+EQL) is 277.403mm and this Joint Displacement reduce due belt wall applied in bare frame is 256.538mm and Joint Displacement also effects on floors having belt wall.
- In 20 storey building maximum Joint Displacement in Bare frame occurs due to load combination 1.0 (DL+EQL) is 277.403mm and this Joint Displacement reduce due Shear wall applied in bare frame is 245.395mm.
- In 20 storey building maximum Storey Drift in Bare frame occurs due to load combination 1.0 (DL+EQL) is 0.006562 and this Storey Drift increase due belt wall applied in bare frame is 0.007363 and Storey Drift also effects on floors having belt wall.
- In 20 storey building maximum Storey Drift in Bare frame occurs due to load combination 1.0 (DL+EQL) is 0.006562 and this Storey Drift reduce due Shear wall applied in bare frame is 0.005401.
- In 20 storey building maximum Drift Ratio in Bare frame occurs due to load combination 1.0 (DL+EQL) is 0.0021873 and this Drift Ratio increase due belt wall applied in bare frame is 0.0024543and Drift Ratio also effects on floors having belt wall.
- In 20 storey building maximum Drift Ratio in Bare frame occurs due to load combination 1.0 (DL+EQL) is 0.0021873 and this Drift Ratio reduce due Shear wall applied in bare frame is 0.0017963.

- In 20 storey building maximum Bending Moment in Bare frame occurs due to load combination 1.5 (DL+EQL) is 1479.326 kN-m and this Bending Moment increase due belt wall applied in bare frame is 1652.4478 kN-m and Bending Moment also effects on floors having belt wall.
- In 20 storey building maximum Bending Moment in Bare frame occurs due to load combination 1.5 (DL+EQL) is 1479.326 kN-m and this Bending Moment reduce due Shear wall applied in bare frame is 751.4964 kN-m.
- In 20 storey building maximum Bending Moment in Bare frame occurs due to load combination 1.2 (DL+LL+EQL) is 1184.9737 kN-m and this Bending Moment increase due belt wall applied in bare frame is 1323.1904 kN-m and Bending Moment also effects on floors having belt wall.
- In 20 storey building maximum Bending Moment in Bare frame occurs due to load combination 1.2 (DL+LL+EQL) is 1184.9737 kN-m and this Bending Moment reduce due Shear wall applied in bare frame is 522.67683 kN-m.
- In 20 storey building maximum Shear force in Bare frame occurs due to load combination 1.5 (DL+EQL) is 797.1496 kN and this Shear force increase due belt wall applied in bare frame is 889.2252 kN and Shear force also effects on floors having belt wall.
- In 20 storey building maximum Shear force in Bare frame occurs due to load combination 1.5 (DL+EQL) is 797.1496 kN and this Shear force reduce due Shear wall applied in bare frame is 558.00472 kN and Shear force also effects on floors having Shear wall.
- In 20 storey building maximum Shear force in Bare frame occurs due to load combination 1.2 (DL+LL+EQL) is 639.2361 kN and this Shear force increase due belt wall applied in bare frame is 712.6188 kN and Shear force also effects on floors having belt wall.
- In 20 storey building maximum Shear force in Bare frame occurs due to load combination 1.2 (DL+LL+EQL) is 639.2361kN and this Shear force reduce due Shear wall applied in bare frame is 271.3837 kN.
- In 20 storey building maximum Base Shear in Bare frame occurs due to load combination 1.5 (DL+EQL) is 77039.914 kN-m and this Base Shear due belt wall applied in bare frame is 86269.426 kN-m Base Shear also effects on floors having belt wall. When Shear wall applied in bare frame is 89635.021 kN-m.

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